

# GUIDED WAVE STRUCTURAL HEALTH MONITORING AT U OF M

**Prof. Carlos E. S. Cesnik**

*Director, Active Aeroelasticity and Structures Research Laboratory*

*Department of Aerospace Engineering, The University of Michigan, Ann Arbor, Michigan*

Research at the University of Michigan (U of M) is directed towards fundamental issues pertaining to guided wave (GW) structural health monitoring (SHM) in aerospace structures. This approach involves exciting GWs in structures with high frequency narrow bandwidth signals and gauging structural health by analyzing the response of the structure. Typically, surface-bonded/embedded piezoelectric wafer transducers are used. It has shown great potential as a reliable method to locate and characterize damage in several initial laboratory demonstrations. GW SHM finds its origins in the field of ultrasonic Non Destructive Evaluation (NDE).

GW testing can be somewhat complex because more than one mode can be excited in a structure at any frequency. Furthermore, the modes are dispersive, i.e., different frequencies travel at different wavespeeds. Hence, a fundamental characterization of the GW field excited and sensed by the piezo transducers is essential. Efforts at U of M have been focused on high-fidelity 3-D elasticity-based models in isotropic structures to model high-frequency GW propagation in various configurations. Based on these models, a comprehensive set of *Design Guidelines* for GW SHM systems in metal structures has been developed, covering all the parameters involved. Similar work has started to address GW excitation in composite structures. For plate structures, a generic formulation to model excitation and sensing by arbitrary shape piezo-actuators has been developed and specific expressions for commonly used shapes (ring-shaped and rectangular) have been derived. Directional transducers made of Macro Fiber Composite (MFC) have also been pursued. These are specially developed anisotropic piezo-composite transducers with greater robustness, flexibility, conformability to curved surfaces and actuation authority compared to conventional piezoceramics. Excitation and sensing of GWs by MFC transducers in beams, plates and shells have also been addressed. These models are backed strongly by numerical verification and experimental validation (see Fig. 1).

For damage detection resolution, a new signal-processing algorithm has been developed with several advantages over conventional algorithms. This algorithm is based on chirplet matching pursuits, a relatively new development in signal processing. The algorithm is computationally efficient and well suited for automated post-processing as required for real-time health monitoring. In addition, as verified in simulations and experimental tests with isotropic structures, it is capable of isolating and identifying overlapping, multimodal reflections of GWs from defects (Fig. 2). It could locate closely spaced (2 cm) damage sites with a maximum deviation of less than 1 cm in aluminum plates. These could not be resolved by conventional algorithms. In cases where damage sites were further spaced, the maximum deviation was less than 0.5 cm. Currently, tests to examine the algorithm's robustness to external factors such as temperature and load are underway. In the future, an analogous algorithm will be developed for composite structures. Furthermore, modeling of GW scattering from commonly encountered defects such as cracks, impact damage, and delaminations in composites will be explored to enable better defect characterization.

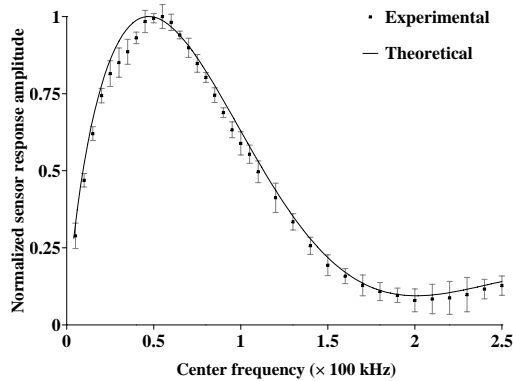


Fig. 1: Sample experimental validation result for circular actuators on isotropic plates ( $A_0$  mode)

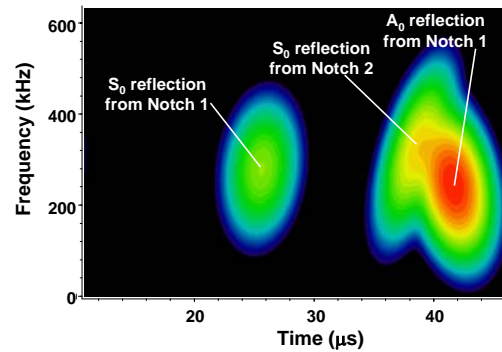


Fig. 2: Sample result from new signal processing algorithm demonstrating its ability to resolve overlapped reflections from damage sites